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Ecological Momentary Assessment in Eating Disorder and Obesity Research: a Review of the Recent Literature

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Abstract Our current understanding of the etiology and maintenance of eating disorders and obesity continues to be far from complete. Similarly, our understanding of determinants of both successful and unsuccessful weight loss surgery is also quite limited. While a number of research methodologies have been applied to these areas, one methodology that has recently seen a rise in popularity is the use of ecological momentary assessment (EMA). EMA allows one to study a variety of variables of interest in the natural environment. The study of eating disorders, obesity, and bariatric surgery has all been conducted using EMA recently. The current study is a review of these areas and summarizes the recent literature (past 3 years) in eating disorders, obesity, and bariatric surgery using EMA methodology.

Keywords Ecological momentary assessment · Momentary assessment · Naturalistic assessment · Eating disorders · Disordered eating · Obesity · Bariatric surgery · Gastric bypass surgery

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Introduction

Ecological momentary assessment (EMA), a term first coined by Stone and Shiffman [1], involves the repeated real-time sampling of a person's current behavior and/or experiences in their natural environment. It involves prompted or participant-initiated self-report ratings of behavior, experiences, and environmental conditions that are gathered "in-the-moment". EMA was developed to address many of the limitations of traditional research approaches. First, by focusing on current events and experiences, EMA minimizes the recall biases associated with retrospective self-report [1, 2]. Second, by collecting real-world data in the natural environment, EMA serves to maximize the ecological validity and generalizability of the assessments. Finally, EMA is inherently intensive, typically collecting multiple observations per day for periods of several days, weeks, or even months. This provides the opportunity to study the temporal patterns and momentary processes that influence behavior in the natural environment.

Advancing Technology and EMA

The technology used to capture real-time, naturalistic data has undergone considerable transformation over the past two decades. Early real-time assessments were gathered using paper-and-pencil notebooks and wristwatches that signaled participants when it was time for an assessment [3]. However, this methodology did not allow for the measurement of compliance with the scheduled assessment times and research has clearly shown that participants are often not honest about when they report data [4]. Electronic devices that allowed for date and time stamping represented a significant advance in data collection and resulted in the methodology we now call EMA. Palmtop computers (e.g., PalmPilot™) allowed for data

entries to be both date and time stamped and offered a relatively stable and reliable means of data collection. While this type of device is still used today, a few factors have contributed to researchers more often using different options for real-time data collection. First, most of these options required participants to meet face-to-face with research staff for their data to be uploaded. This added burden and was inconvenient for participants. Second and related to the first point, although data could be procured from participants remotely via a modem upload, a very large percentage of potential research participants were using digital phone lines or cellular phones, both of which made modem uploads impractical or impossible. However, part of this problem resulted in the latest line of data collection devices: cellular phones are used by a large and growing percentage of Americans and EMA researchers sought to exploit this fact.

Application, text messaging, and web-based options have been developed for the purposes of gathering real-time data from participants (e.g., the system our research group uses can be found at http://retaine.org/). This technology offers a large number of advantages, including the ability to make use of hardware that the participant is already familiar with (i.e., typically they can use their own phone) and nearly immediate access to the data a participant provides.

Since the review article by Smyth and colleagues in 2001 [5] describing EMA as an ideal methodology to study the behaviors and experiences associated with eating and eating disorders, the use of such methods to study eating behaviors and pathology has increased dramatically. While EMA has been used much less frequently in the area of obesity and following weight loss surgery, an increasing number of researchers are using EMA and related technologies in these populations. As such, we believe that a review focusing on EMA as a methodology for studying eating disorders and obesity is important, relevant, and timely. The objective of this narrative is to discuss the current EMA literature, with an emphasis on literature from the past 3 years, and to help the reader gain an appreciation for the increases in our understanding of eating disorders and obesity that have been achieved through the use of momentary data capture methods.

Review of Literature: Eating Disorders

In a past literature review [6], we categorized the extant eating disorder literature that employed EMA into content-based clusters and discussed the basic findings in each category. In the current review, we again use this informal categorization approach, but used an updated approach to categorization of the data to better reflect the contemporary literature. The vast majority of the recent EMA literature in eating disorders could be reasonably placed in four categories which are discussed in this review: (1) model testing, (2) antecedents and consequents of eating disorder behavior, (3) description, frequency, and patterning of eating disorder behavior, and (4) psychometric properties of EMA research in eating disorders. Categorizing the literature in this way should give the reader a reasonable understanding of the recent empirical work that has been done with EMA in the eating disorders field.

Model Testing

As we have detailed in the past, one of the key benefits of EMA is that it allows for the testing of models that are inherently momentary [7]. By our estimation, many of the key variables posited to play a significant role in the development and maintenance of eating disorder function in the moment (e.g., emotion). A number of studies have examined various hypothesized mediators and/or moderators of the association between theoretically relevant variables and eating disordered behaviors e.g., [8–10, 11•, 12]. Other studies have employed EMA methodology to test the momentary associations between key variables in more formal models. For example, Haynos and colleagues [13] examined the emotional avoidance model of anorexia nervosa using momentary data with results suggesting that restrictive eating and negative affect were not related in a manner consistent with the model being tested. In a study based on cognitive behavioral theory, Lavender and colleagues [14] found that body checking frequency on a given day was associated with greater dietary restriction on the same day and following day in anorexia nervosa (AN). Another study examined the dual pathway model of bulimia nervosa using momentary data [15]. They found that both negative affective state and dieting mediate the association between state body dissatisfaction and disordered eating supporting the dual pathway model and the associated role of momentary variables play in it. In a study that employed EMA to evaluate the interpersonal model of loss of control eating, findings by Ranzenhofer and colleagues [16] partially supported the model and demonstrated a significant relationship between momentary interpersonal problems and loss of control eating in adolescent girls. Finally, Fuller-Tyszkiewicz and colleagues [17] have added to our understanding of the affect regulation model by comparing a threshold versus dose-response conceptualization of the model.

Antecedents and Consequents of Eating Disorder Behavior

Because most of the research in this category directly or indirectly tests an affect regulation model of eating disorders it overlaps considerably with the model testing category. However, the study of emotion-related variables and eating disorder behavior has received sufficient empirical study to justify its own category and discussion. Much, but not all, of this work has examined the temporal associations between

affective state and eating disorder behavior. For example, Berg and colleagues [18, 19] published two different papers demonstrating that negative affect, particularly guilt, increased before and decreased after binge eating episodes and that negative affect also is associated with overeating and binge eating days in obese adults. Additionally, Berg and colleagues [20] demonstrated that guilt was particularly associated with binge eating, purging, and binge-purge episodes in individuals with bulimia nervosa. Several reports have recently been published examining individuals with anorexia nervosa using EMA. First, Engel and colleagues [21•] generally found that negative affect significantly increased prior to LOC eating, purging, and LOC eating/purging behaviors and subsequently decreased significantly after the occurrence of these behaviors. The findings in this study were somewhat mixed based on the analytic approach employed, however (see Future of EMA in Eating Disorders and Obesity Research section below). Additionally, Fitzsimmons-Craft and colleagues [22] reported that affect was significantly associated with restrictive eating episodes in this group. In a study of affective variability in anorexia nervosa, Selby and colleagues [23] found both positive and negative affective variability were independently and interactively associated with weight loss activities. A related study also found that the inability to successfully differentiate between facets of positive affect (e.g., excited versus proud) also predicted weight loss activities in anorexia nervosa [24].

Description, Frequency, and Patterning of Eating Disorder Behavior

EMA has been used in a wide variety of ways to describe, assess the frequency of, and attempt to pattern the occurrence of behaviors, thoughts, and feelings related to eating disorder behaviors. For example, Schreiber-Gregory and colleagues [25] used EMA in a sample of nine women with binge eating disorder (BED) to demonstrate that binge eating episodes lasted an average duration of 42 min and were most common in the early afternoon and evening hours. Lavender and colleagues published two reports on affective patterns in AN. In one study they demonstrated that the momentary anxiety levels varied considerably across the day, could be accurately depicted in seven different trajectories, and that eating disorder behaviors were most likely to occur during periods of the highest levels of anxiety [26]. In another study, Lavender and colleagues [27] used EMA to temporally map the days of the week and times during which individuals with AN were most likely to experience high tension/anxiety and when eating disorder behaviors were most likely to occur.

A number of studies have used EMA to measure the frequency of a wide variety of behaviors. For example, Farchaus Stein and colleagues [28] assessed the prevalence of eating disordered behaviors in a sample of Mexican American women. Studying a sample of adolescents who engage in nonsuicidal self-injurious behaviors, Shingleton and colleagues [29] examined the frequency of binge and purge cognitions. There have also been a number of recent studies in AN. De Young and colleagues [30] demonstrated that individuals with AN binge-purge subtype reported more momentary restrictive eating behaviors than individuals with AN restricting subtype. Finally, Goldschmidt and colleagues [31] reported on behaviors, emotions, and situations surrounding purging behavior in AN. Further, Goldschmidt and colleagues [32] used latent profile analysis to describe typical classes of eating and their associations with affective states and compensatory behaviors.

Psychometric Properties of EMA Research

Three studies have recently been published that offer some useful information about the psychometric properties of EMA when used to assess eating disorder-relevant variables. Heron and Smyth [33] found that the use of EMA does not appear to significantly impact the measurement of body image. Wonderlich and colleagues [34] found reasonable convergence between EMA and retrospectively recalled assessments of emotional states, binge eating, and exercise in samples of AN, bulimia nervosa (BN), and obese individuals. Finally, Lavender and colleagues [14] used EMA to compare associations between momentary versus retrospectively assessed emotions constructs and eating disorder symptoms. They found that only affective variability operationalized using data collected via EMA (compared to a self-report measure administered once) was uniquely associated with baseline eating disorder pathology.

Review of Literature: Obesity

Compared to eating disorder research there are fewer studies that have employed momentary measurement in the area of obesity and healthy weight management. One exception, however, includes the considerable amount of research involving objective monitors (e.g., accelerometer devices) to measure physical activity, and to a somewhat lesser extent, sedentary behaviors (i.e., group of behaviors requiring very low energy expenditure), which has been reviewed extensively elsewhere [35–37]. The present discussion is focused on the limited obesity-related EMA literature. In contrast to the content-based categorization scheme, we have organized the obesity literature into two groups based on the sample of interest. These two areas are as follows: studies focusing on adults and research on children/adolescents.

Adult EMA Obesity Research

The first group of studies involve those examining physical activity. An EMA study of low-activity adults found that home was the most common location for physical activity and sedentary activity, and both were more likely to occur when alone [38]. Outdoor home locations and outdoor park locations were where moderate-to-vigorous physical activity (MVPA) was most likely to occur for women and men, respectively. A study of overweight and obese participants diagnosed with knee osteoarthritis found a diurnal trend in pain and pain tended to increase immediately after exercise, although only temporarily [39] In another study using daily diaries to evaluate physical activity in older adults participating in a physical activity intervention, mood was positively affected by exercise, particularly among individuals with depressed baseline mood levels [40]. A final EMA study of older adults found that high levels of physical activity were associated with greater physical activity self-efficacy, positive affect, perceived situational control, and lower levels of negative affect in the prior EMA rating [41]. Increased physical activity was also associated with having a positive social interaction on the concurrent EMA rating.

A number of studies have been conducted to explore patterns of eating related to obesity and weight management. For instance, [42] found that individuals with a lower BMI were found to have a relatively low rate of overeating regardless of the number of palatable, high calorie foods present, while those with higher BMIs had much higher rates of overeating when these foods were present and lower rates in the absence of these foods. In another study evaluating eating behavior in young women, results revealed that restrained eaters (i.e., chronic dieters with a history of weight fluctuations) ate less in the period immediately following elevations in positive or negative mood, did not overeat in response to anxiety, and ate more in response to hunger [43]. A small EMA study found that eating episodes occurred more often in a positive versus negative emotional context and that eating influenced their emotional state more in emotionally positive situations than in emotionally negative ones [44]. Also, another EMA study in young adults showed that eating occasions commonly occurred alone, while watching television or other activities, and with little planning or meal selection [45]. Furthermore, eating at home, with others, and in the absence of multitasking were related to healthier dietary choices. In a study of obese adults, compared to nonpathological eating episodes, binge eating and loss of control eating were preceded and followed by elevated negative affect, binge eating was preceded by lower hunger, and binge eating and overeating were followed by lower hunger [32]. Finally, an EMA study of overweight and obese adults with osteoarthritis found that experiencing pain was associated with higher calorie and fat intake [46].

EMA studies have also explored food craving, temptation (coming close to "breaking" a diet), and lapse ("breaking" a diet) during a weight loss attempt. A diary study showed that women who were dieting experienced more food cravings than non-dieters and dieters experienced more difficult to resist cravings and cravings for restricted foods than non-dieters [47]. Studies of overweight female dieters found that increased hunger was associated with both temptation and lapse [48], and temptation mediated the effect of hunger on lapse [49]. In addition, low satiety was associated with temptation only, and decreased satiety following the last meal was associated with lapse only [48]. Situational factors such as social events, watching television, being in a location where food was likely to be present (e.g., at home), actively consuming food, unexpected temptations, and less positive coping response increased risk of lapses [48, 49]. In addition, presence of others, unexpected temptations, and less positive coping response increased the perceived strength of temptations [49]. Interestingly, use of coping strategies was more common during temptation versus lapse, suggesting that some lapses were averted by use of coping skills [50]. Temptation and lapse were also associated with negative mood states, [48] and lapses were associated with low confidence in the diet [48] and lower efficacy to resist future temptations [49]. Poor weight loss outcomes were associated with feelings of guilt and failure, but the frequency of temptation and lapse was not associated with weight loss [51]. Elevations in both positive and negative mood were associated with lapses and lapses resulted in feeling of guilt and failure [50].

Recent studies have begun to use EMA to examine experiences of weight stigmatization among overweight and obese adults. One study reported that weight stigma was experienced about once a day [52] and was most commonly perpetuated by strangers, partners, and friends, was mostly delivered via verbal comments, and occurred mostly at home or in a combined public place. Weight stigma was associated with less negative affect when the perpetrator was a partner or media source compared to a stranger. A separate daily diary study of 50 overweight or obese women found that higher BMI, increased interpersonal interactions, and a higher amount of indoor activities were associated with more weight stigma in daily life [53]. In addition to weight stigma, a naturalistic study found that experiencing fat talk was associated with greater body dissatisfaction, body checking, negative affect, and disordered eating and participating in "fat talk" also resulted in more body checking comparing to hearing "fat talk" [54].

A single EMA study has been conducted with bariatric surgery patients in a sample of 21 cases with an average of 6 months after surgery [55, 56]. The study showed that most participants stopped eating upon feelings of satiation and complied with medications and supplements, but participants tended to eat too infrequently, and meals were often too large and consumed too quickly [55]. In addition, an examination of

their physical activity behavior found that participants intended to be active on 66 % of days, but these intentions were met on only 18.5 % of days [56].

Child and Adolescent EMA Obesity Research

In children and adolescents, the clear majority of obesity-related EMA studies have been conducted on the topic of physical activity and sedentary behavior, with particular emphasis on describing the behaviors, their predictors, and the contexts in which they occur. From a methodological perspective, there is evidence that mobile phones can be used with children and adolescents to collect self-reported physical activity data, and contextual information pertaining to the type of activities performed, without having a substantial effect on the activities themselves (i.e., reactivity). In addition, studies have demonstrated the accuracy of self-reported physical activity via EMA by corroborating EMA data with objective physical activity monitors [57, 58].

EMA studies have consistently shown low levels of physical activity and high levels of sedentary behaviors in children and adolescents, which is consistent with reviews of objectively monitored activity levels. Data show that boys spend more time in exercise than girls, but that girls spent more time walking than boys [58–61]. Watching television accounted for the greatest amount of sedentary time [59, 60, 62, 63] and primarily occurred at home [64]. Additionally, higher BMI was associated with more time spent focused primarily on television watching [65].

Studies showed that physical activity occurred most commonly outdoors, with peers, and at school [66–68] and those who spent more time outdoors and with peers were more likely to have higher levels of physical activity [69]. A temporal and contextual analysis of the data suggested physical activity was more likely to occur in the afternoon, with sedentary activity, particularly watching television, in the evening [70]. Physical activity occurred more often when participants were outdoors, although the strength of this association was weaker for older adolescents (compared to those who were younger). A study using an accelerometer and GPS device [71] found that a relatively low amount (1.9 %) of physical activity was performed in parks, although the proportion was higher in obese children (2.7 %; compared to non-obese children). In a study comparing children who had recently moved to a "smart growth" community designed to enhance walkability and open space to controls, [72] moving to the smart growth community did not result in increased physical activity compared to controls, but children in the smart growth community showed increased physical activity performed with friends and at locations near home that were reached by walking. There were similar decreases in physical activity performed indoors at home and in high traffic locations. High activity children (i.e., those in the top tertile of moderate-to-vigorous physical activity per hour as measured by accelerometer) were found to be more active indoors, and performed more specific activities such as running crawling and climbing, but there were no differences between high- and low-activity children on total outdoor activity, demographics, or level of parental education [73]. Also, children who felt more energetic reported engaging in more moderate-to-vigorous physical activity, which was associated with increased subsequent positive affect and feeling energetic [74]. In another EMA protocol, physical activity was also related to happier mood and occurred more often with peers than when alone [61]. On weekends, increased MVPA was associated with eating breakfast among both boys and girls [75].

Very few EMA studies have been conducted with children on topics unrelated to physical activity and sedentary behavior. An EMA study with 158 adolescents from low income neighborhoods showed that consumption of sweet and salty snacks and sweet drink consumption was associated with being at school, being with friends, feeling lonely or bored, craving a drink or snack, and being exposed to food cues [76]. Sweet drink consumption was also related to physical activity and sweet snacks were associated with watching television. One final study used EMA to assess diet and physical activity among eight adolescents who underwent bariatric surgery [77]. The data showed that few of the adolescents met postoperative physical activity and dietary guidelines.

Conclusion

The literature reviewed above focused on recent research utilizing EMA in the study of eating disorders, obesity, and bariatric surgery. However, the recent literature in these areas covers an extremely wide variety of topics, variables, and patient groups. EMA research has been conducted for over two decades and the application of this methodology to obesity and eating disorders is clearly beginning to be more frequently employed by researchers in these fields. That being said, given that many of the key variables posited to play a significant role in eating disorders and the development of obesity are inherently momentary (e.g., affect, activity, eating behaviors) continued research using EMA will provide further data to better inform our understand of the development and maintenance of these conditions, as well as their prevention and treatment.

In the area of eating disorders, the relationship between affect and eating disorder behavior is increasingly clear: negative affect increases over time until the point at which eating disorder behavior occurs [5, 6, 78]. Exactly what happens to affect after an eating disorder behavior occurs is less clear. Some research suggests that negative affect decreases after eating disorder behaviors occur [5] while other findings suggest that it does not decrease, or continues to increase [78].

Gaining a better understanding of how affect temporally relates to eating disordered behavior, particularly following the behavior, will help to clarify the functional role that affect may play in the etiology and maintenance of an eating disorder. We believe an underappreciated caveat to this point is that the analytic approach employed may have considerable impact on the appearance of the affect-behavior relationship. Some research has employed analytic approaches using both a "all data points available" approach as well as a single point (one pre-behavior affect rating and one post-behavior rating) and found discrepant results depending upon which analytic approach is employed [6]. Understanding the differences and nuances associated with each approach is important when considering which approach to use. While some work has been done to clarify this issue [19] a better understanding of this issue would help to inform eating disorder models and potentially treatment.

Obesity and bariatric surgery remain an underdeveloped area for the application of EMA methodology. There is tremendous need and opportunity to collect naturalistic information about core obesity-related processes that lead to excess energy intake, low physical activity, and high levels of sedentary behavior. EMA is a particularly good fit for this type of research because the significant role the environment plays in the obesity epidemic may be difficult to measure in a laboratory setting, and that have relatively small effects in any one moment but large cumulative effects over time [79]. EMA is able to capture repeated exposures to the environment so that the complex reciprocal effects with behavior can be studied holistically, including their temporal ordering. This more fine grained analysis of the behavioral etiology and maintenance of obesity could help shape future interventions, particularly as ecological momentary intervention (EMI) and personalized medicine become increasingly prevalent. Studies have demonstrated the feasibility of EMI for weight management and other health interventions in adults ([80, 81•] and children and adolescents [82–85]. Integrating self-report data with information from objective monitoring devices such as accelerometers, geolocation, and medical devices (e.g., continuous glucose monitors, continuous alcohol sensors, etc.) will play an important role in meeting this goal. Integrating EMA with other forms of ambulatory assessment may also help to answer questions about the development of obesity that we were simply unable to address before these methodologies were available.

Bariatric surgery patients are an important subgroup within the population of obese individuals that could benefit from more extensive EMA research. Each surgical procedure is associated with unique behavioral effects (e.g., dumping syndrome) and requirements, yet very little is known about cognitive, behavioral, and physiological patterns that contribute to weight loss success, inadequate weight loss, weight regain, medical complications, and the need for revisional surgery. The use of EMA also affords a unique opportunity to collect data about eating behaviors, physical activity, and surgery-related complications in real-time, which could facilitate more timely and effective intervention with bariatric surgery patients.

Compliance with Ethical Standards

Conflict of Interest Scott G. Engel, Graham Thomas, Dale Bond, Jason M. Lavender, Tyler Mason, Kristine J. Steffen, Dan D. Green, and Stephen A. Wonderlich declare that they have no conflict of interest.

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Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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